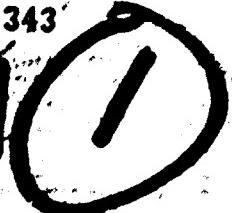


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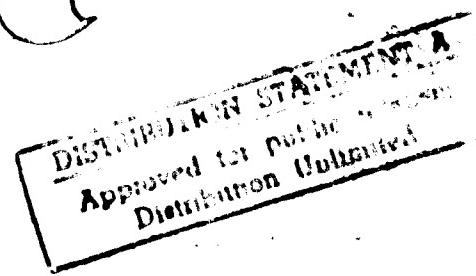
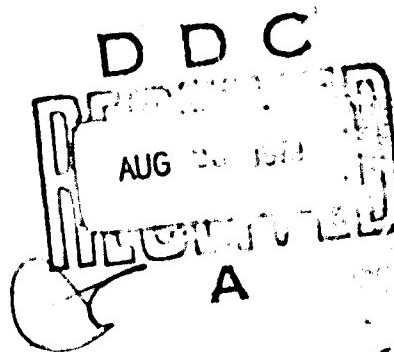


COMMENTS ON AIR TO AIR VISIBILITY AT HIGH ALTITUDE

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5 August 1954



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Washington, D.C.

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A B S T R A C T

Aviators flying at high altitude report difficulty in sighting other aircraft. The factors causing this poor air-to-air visibility are discussed, particularly the phenomenon of "empty field" myopia. It is concluded that the correction of the myopia may moderately improve air-to-air vision. An experiment for quantitatively determining the improvement is proposed, and some practical methods of correcting the empty field myopia are suggested.

A U T H O R I Z A T I O N

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INTRODUCTION

The difficulty of visually detecting high flying aircraft, when the observer is in an airplane flying at approximately the same level, is well known, and some means of improving air-to-air spotting is needed. Typical difficulties reported¹ when flying at high altitudes are:

- (1) an aircraft may come very close before it is sighted;
- (2) if an aircraft is sighted, the observer may look away for a moment and then be unable to find the plane when he again looks toward it;
- (3) if the aircraft is located by radar and its position established, it is still not seen until it comes very close.

There are many factors believed to cause the above visual difficulties at high altitude; a frequently mentioned factor is the phenomenon of "empty field myopia", which is a state of nearsightedness induced by looking into a large empty field such as a cloudless sky.

Below are listed the principal factors which may make aircraft hard to detect at high altitude. Each is discussed in some detail. In some cases there is an estimate of the importance of the particular factor and a suggestion as to what can be done about it. Empty field myopia is discussed in considerable detail at the end of the list, and following this are some suggested means of correcting the empty field myopia in pilots and observers. Also suggested are experiments designed to determine quantitatively the gains obtained in correcting empty field myopia.

PRINCIPAL FACTORS AFFECTING VISUAL DETECTION OF AIRCRAFT AT HIGH ALTITUDE

1. Glare. Many persons get an impression of greater brightness at high altitudes than at low altitudes.² Since the sky gets dimmer as one goes up, this impression must arise from the fact that the sun becomes more and more objectionable as a glare source, its direct rays being less and less attenuated as one goes up. The sun on surrounding plane parts no doubt adds to the glare. In addition, the presence of undercast, etc., will brighten the lower half of the visual field, which under ordinary circumstances is dark. All these factors will worsen the pilot's vision. The situation can be alleviated somewhat by entirely obvious means such as sun visors, darkening parts of the plane, etc. The pilot can of course wear sun glasses to avoid discomfort from glare, but visibility of objects in the sky will be reduced. In general there appears to be no satisfactory way of eliminating glare from the sun.

2. Low Contrast. Assuming that a high flying plane is not jet-black, it may have a contrast positive, negative, or zero with respect to its background, depending upon position of sun, observer, etc. For a plane of average reflectance it would not be surprising to find the contrast oscillating about the zero value, the plane being sometimes a little brighter than the sky, frequently a little darker. At least one worker regards poor visibility at high altitudes as the result of low contrast ratios.¹ Duntley stated in 1952 that "The Visibility Laboratory has under

construction several spherical enclosures ---- which will serve as artificial skies within which model aircraft can be photometered to determine their inherent contrasts under flight conditions."³ Such data would settle the point and it is possible that these data are now available. Anyway the contrast in any set of circumstances is what it is, and there is little the observer can do about it. However, if poor visibility is due mostly to low contrast then one need not worry so much about trying to correct some other factors.

3. Relative Motion. The speed of jet aircraft is such that they may pass in and out of the range of vision very quickly, at least under some circumstances. It is obvious that short search time and large relative motion will reduce the detectability of other aircraft, and it is just as obvious that there is little to be done about it. Only the pilot can change the situation to some extent by his own maneuvers.

4. Narrow Field of Vision. For an object near the threshold of detectability, the visual field is very small (less than a degree) and the object is lost the moment the eye turns slightly away. This means that in searching the sky for small objects, the cone in which detection is possible is very narrow - less than a degree - and the observer might as well be searching while looking through a two-foot length of half-inch pipe. As the object becomes larger the visual field over which it can be detected becomes larger. For example, a few crude measurements made at NRL indicate that a black object on a sky background is detectible in a cone of 3° when

it is about 2 times the threshold size, detectible over a 10° field when it is 4 times threshold size, and over a 26° field when it is 7 times threshold size. These figures would seem to indicate that an object would have to be perhaps 4 times threshold size to have a moderate probability of being detected by randomly searching a large sky area for a reasonable time. For low contrast objects the situation is even worse. Welsman and McCullough, incidentally, have given data which give even narrower visual fields than the NRL data.⁴ There appears to be no simple means of increasing the visual detection probability except to make scanning more systematic or to put more observers in the plane.

5. Difficulty of Systematically Scanning the Sky. The high altitude pilot must feel as if he is embedded in empty space, with only the position of the sun and shadows in the cockpit as signs of change in direction. There is a lack of external landmarks (except the sun) which would ordinarily serve as reference points for systematic visual scanning of the sky, and it would seem that this would be a contributing factor in poor air-to-air visibility.

If the aircraft pilot wants a landmark fixed in space the only means that suggests itself is a gyro-mounted gunsight-type reticule.

6. Empty-field Myopia. It has been found that when viewing an empty-field, such as the sky, the eye assumes a somewhat accommodated state. This state seems to be somewhat unstable, varying between 0.2 and 0.9 diopter, with a mean of 0.5 diopter.⁵ It is believed that the phenomenon is caused

by the fact that the eye has nothing to focus on, and thus tends to seek a position of rest, which happens to correspond to an accommodation of about 0.5 diopters (on the average) for emmetropes. It is not well known how long it takes the eye to settle into the myopic "rest" state; Whiteside and Campbell⁵ indicate that it may take as much as a minute after a stimulus to far vision is removed (see their Fig. 5 and text). It is not known how long it takes the eye to achieve the rest state after looking at a relatively near object such as the interior of an airplane cockpit.

Whiteside and Campbell⁵, and Whiteside and Gronow⁶ in Britain have investigated the problem of empty field myopia rather extensively, and the latter conclude that because of empty field myopia "the farthest distance at which it is possible to pick up a target in the sky will be reduced by half, if there is no cloud or other detail to guide the eye to focus at infinity. It is suggested that aircraft may be spotted at high altitude, when there is no cloud present in the distance, at twice the range, if the eye is made to focus at infinity by employing a device such as the gunsight with its collimated graticule, or else a specially designed, collimated pattern seen by partial reflection".⁶

Some of our own work at NRL confirms the British finding^{6,7} that the retinal blurring caused by 0.6 to 0.7 diopter of myopia increases the size of the minimum perceptible by a factor of about 2. Thus it would indeed seem that aircraft could be detected at twice the range (neglecting

atmospheric attenuation) when the empty field myopia is corrected. However, it must be borne clearly in mind that these conclusions are based on experimental work involving small dark high-contrast objects which are on the threshold of visibility. It has been pointed out in (4) that such objects are perceptible only in the central portions of the visual field and are lost when more than 1/2 degree from the visual axis. Thus such an object placed at random in a large empty field has a rather negligible chance of being detected at all, even with the empty-field myopia corrected.

Therefore it seems proper to forget about objects at the threshold of visibility and deal with objects having a greater angular subtense, and which stand a chance of being detected by visual search of a large field. The question to be asked then is something like this:

How large is the visual field for an object say 2 times threshold size, and how much larger does this field become when the blurring due to empty-field myopia is eliminated? The same question could be asked for objects say 4 times and 8 times the threshold size.

A few crude measurements just completed indicate that for a black object 2 times the minimum perceptible of the emmetropic eye, the visual field is about 1 1/2 degrees when vision is blurred with 0.5D of myopia; the field widens to 3° when the myopia is corrected. For an object 4 times threshold subtense the field is 6° for 0.5D of myopia and widens to 10° when the myopia is corrected. For 7 times threshold the field is 22° with 0.5D of myopia and widens to 26° with myopia corrected. These data are plotted in Fig. 1, which shows the size of the field over which the

object can be detected vs. the factor above threshold. Data are plotted for the emmetropic eye, 0.5D of myopia and 1.0D of myopia. These data show that correction of myopia widens the field relatively more as the field (i.e. chance of detection) becomes less and less. Thus it seems reasonably certain that for a large empty field, the correction of myopia will not improve greatly the detection of objects subtending the minimum perceptible angle; nor will it improve the detection of objects which are greatly above minimum perceptible, since the latter are detected over about the same extent of visual field whether or not the myopia is present. However, there exists a range of intermediate sized objects where correction of myopia may significantly increase the probability of visual detection in an empty field. This point should be investigated since the improved detection of objects in this particular range of angular subtense would seem to be of great importance.

Of all the factors involved in poor air-to-air visibility, the empty-field myopia is the one easiest to do something about, and it seems worthwhile to attempt the correction of empty-field myopia even though the overall gains to be derived therefrom are expected to be moderate.

SUGGESTED METHODS OF CORRECTING EMPTY-FIELD MYOPIA

A. Negative spectacles. The simplest way of correcting empty-field myopia would be to have the observer wear negative spectacles of the proper power. It is here assumed that the myopia occurs as soon as the observer

looks out of the cockpit into the sky. The experiment seems to be worth doing since Whiteside and Gronow⁵ offer evidence that hypermetropes see objects in an empty field at greater range than do emmetropes. An emmetrope with negative spectacles is essentially a hypermetrope. The experiment can be performed by actually giving pilots negative spectacles of the proper power (the empty field myopia of each individual being determined experimentally) and having the pilot report as to their value, or the whole thing could be done more quantitatively in the laboratory.

B. Collimated reticules. Some type of collimated reticule, similar in principle to the reflex gun sight could be placed over the pilots eyes to aid him in focusing his eyes for infinity. The apparatus should be binocular, so that the eyes have a convergence cue to aid in focusing. The device could be evaluated by the pilots in actual flight or the evaluation could be done in the laboratory to see if its use gave a significantly greater number of detections in a large "empty" field.

A SUGGESTED EXPERIMENT FOR DETERMINING THE GAINS TO BE DERIVED FROM CORRECTING EMPTY FIELD-MYOPIA

The experiment to be performed has already been mentioned in (6) and consists of determining the extent of the visual field over which a small test object can be detected when certain degrees of retinal blurring are present, as well as when the eye is properly focused for infinity. The blurring could be induced by positive spectacle lenses of powers say +0.5, +.75, +1.0. This would simulate myopia of these amounts. The extent of the

field could be determined in many ways, the simplest of which is the method used by Welsman and McCulloch.⁴ The experiment should be done with binocular vision at field brightnesses in the range 100 to perhaps 1000 foot lamberts, which covers the range of sky brightnesses likely to be encountered. The horizontal and vertical meridians of the field should be checked, and probably the 45° meridians also. Test objects having various contrasts should be used. These data could be used to calculate, after the manner of Lamar,⁸ the probability of detecting a certain sized object as a function of its position in the visual field, for various values of myopia and for the emmetropic eye. The probability of detection could then also be calculated for a particular scan pattern, for various values of myopia and for the emmetropic eye.

There is no way of predicting the gains derived from correcting empty-field myopia until the above experiments have been done. However, some sort of advance answer can perhaps be gotten via following question: Are there any pilots now flying who are particularly good at detecting other aircraft in the sky? If there are such, they are probably slightly hypermetropic individuals (i.e., they have a built-in correction for empty-field myopia) and they have in addition developed an efficient scan pattern. The correction of the myopia in ordinary individuals might then be expected to raise their performance to the level of these exceptionally good observers, but not beyond it.

OBJECT SIZE (NUMBER OF TIMES ABOVE THRESHOLD)

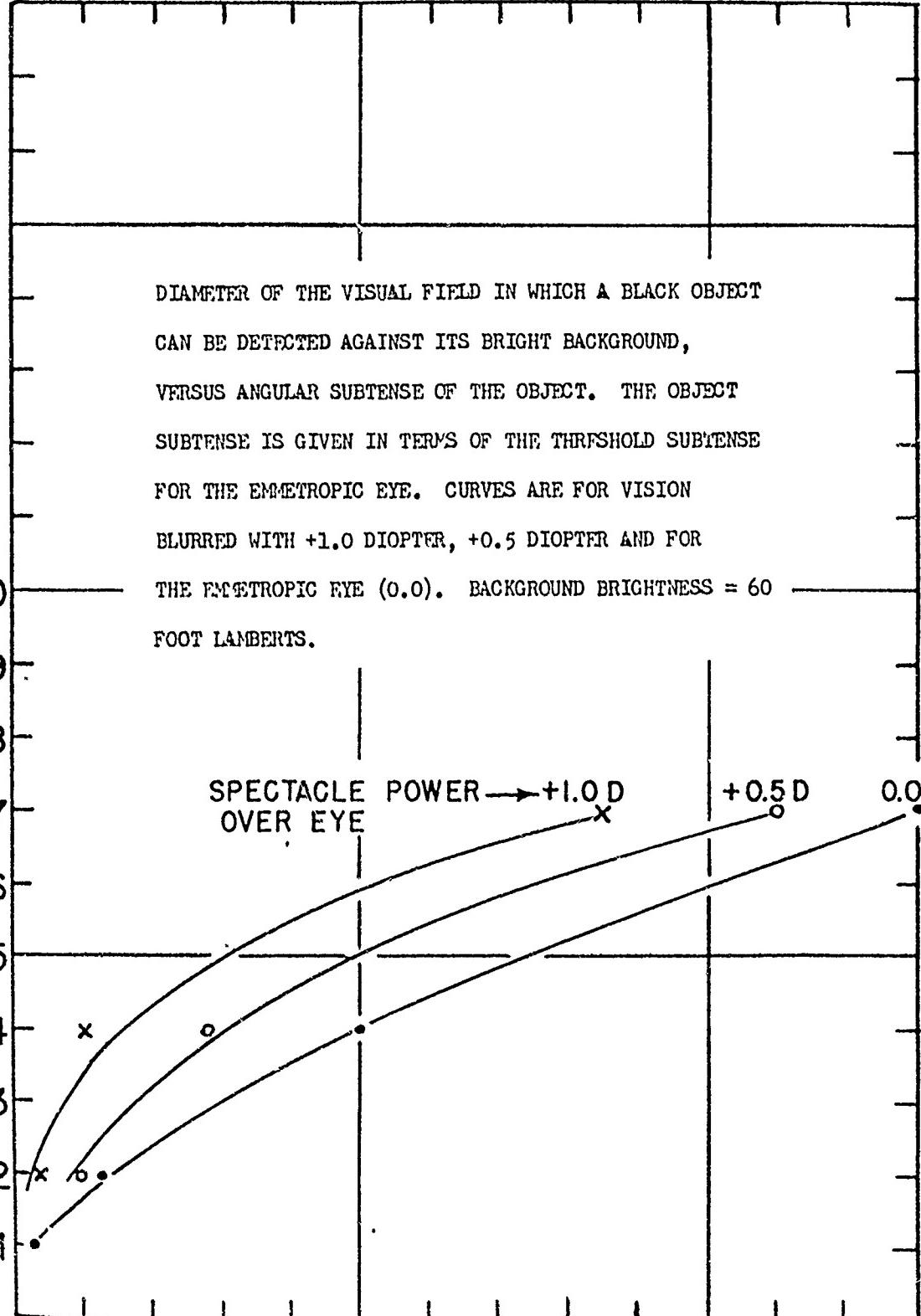
DIAMETER OF THE VISUAL FIELD IN WHICH A BLACK OBJECT
CAN BE DETECTED AGAINST ITS BRIGHT BACKGROUND,
VERSUS ANGULAR SUBTENSE OF THE OBJECT. THE OBJECT
SUBTENSE IS GIVEN IN TERMS OF THE THRESHOLD SUBTENSE
FOR THE EMMETROPIC EYE. CURVES ARE FOR VISION
BLURRED WITH +1.0 DIOPTER, +0.5 DIOPTER AND FOR
THE EMMETROPIC EYE (0.0). BACKGROUND BRIGHTNESS = 60
FOOT LAMBERTS.

SPECTACLE POWER → +1.0 D
OVER EYE

+0.5 D

0.0 D

DIAMETER OF FIELD, DEGREES



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8. E. S. Lamar, Minutes of Armed Forces-NRC Vision Committee, April 1951, p. 43-53.